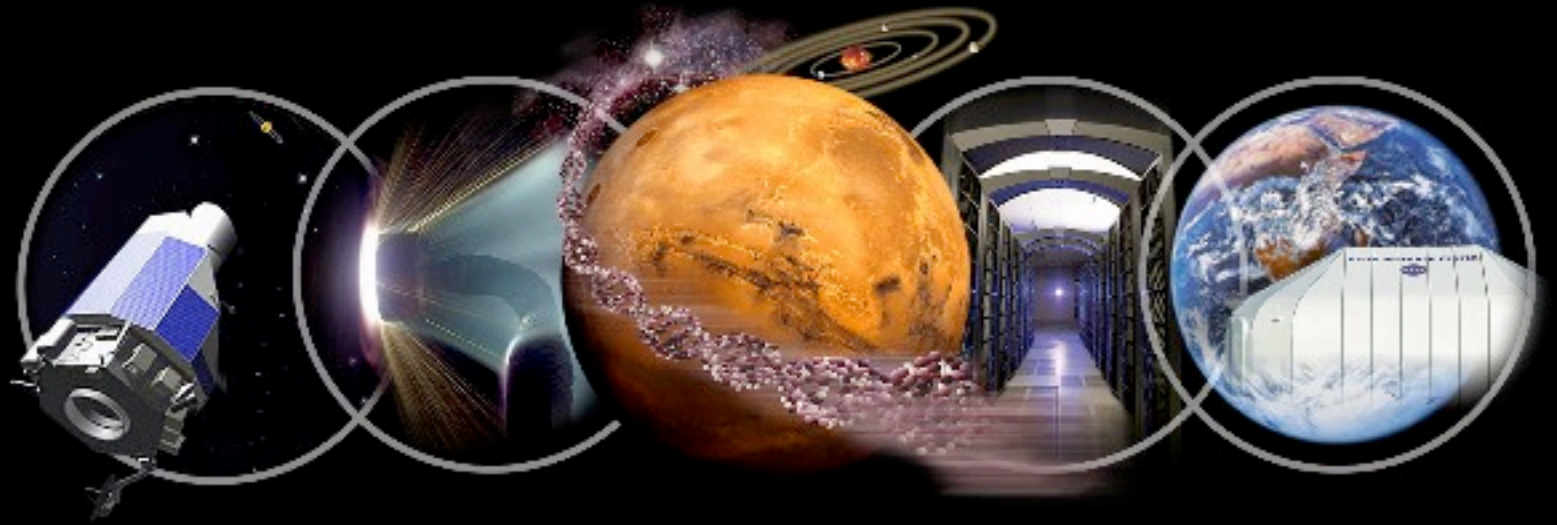
Discovery ➲ Innovation ➲ Solutions



Human Factors of IVHM on Next-Generation Vehicles

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NASA Ames Research Center

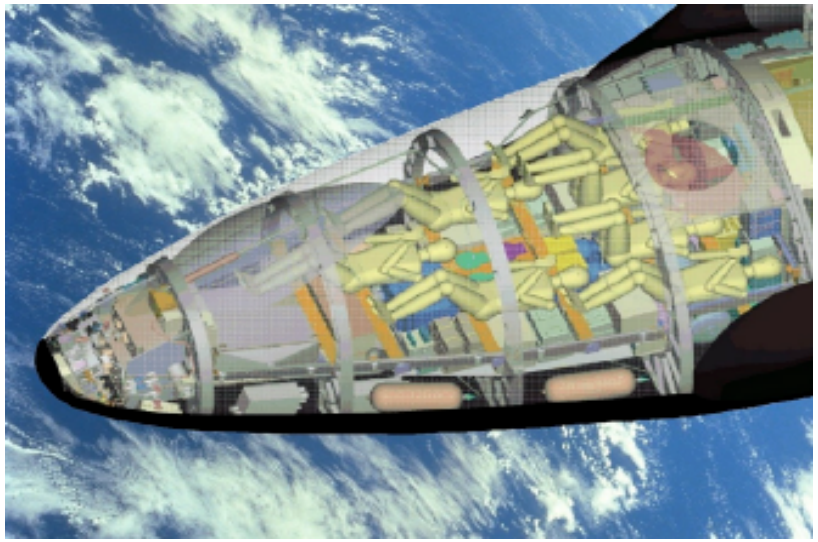
Visibility ➲ Excellence ➲ Impact

Ames Research Center

Human Factors of IVHM on Next-Gen Vehicles

- Current Space Transportation (Shuttle) System will be used to finish ISS responsibilities, and retired in 2010
- New Exploration Transportation System

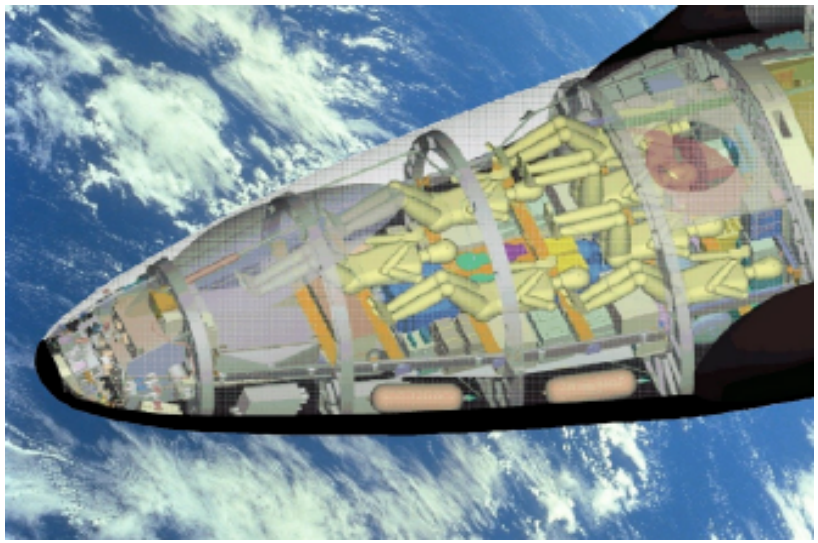
- Crew Exploration Vehicle (CEV)



- LEO Missions by 2011
- Lunar Missions by 2018

Human Factors of IVHM on Next-Gen Vehicles

What's the operating concept for these vehicles?



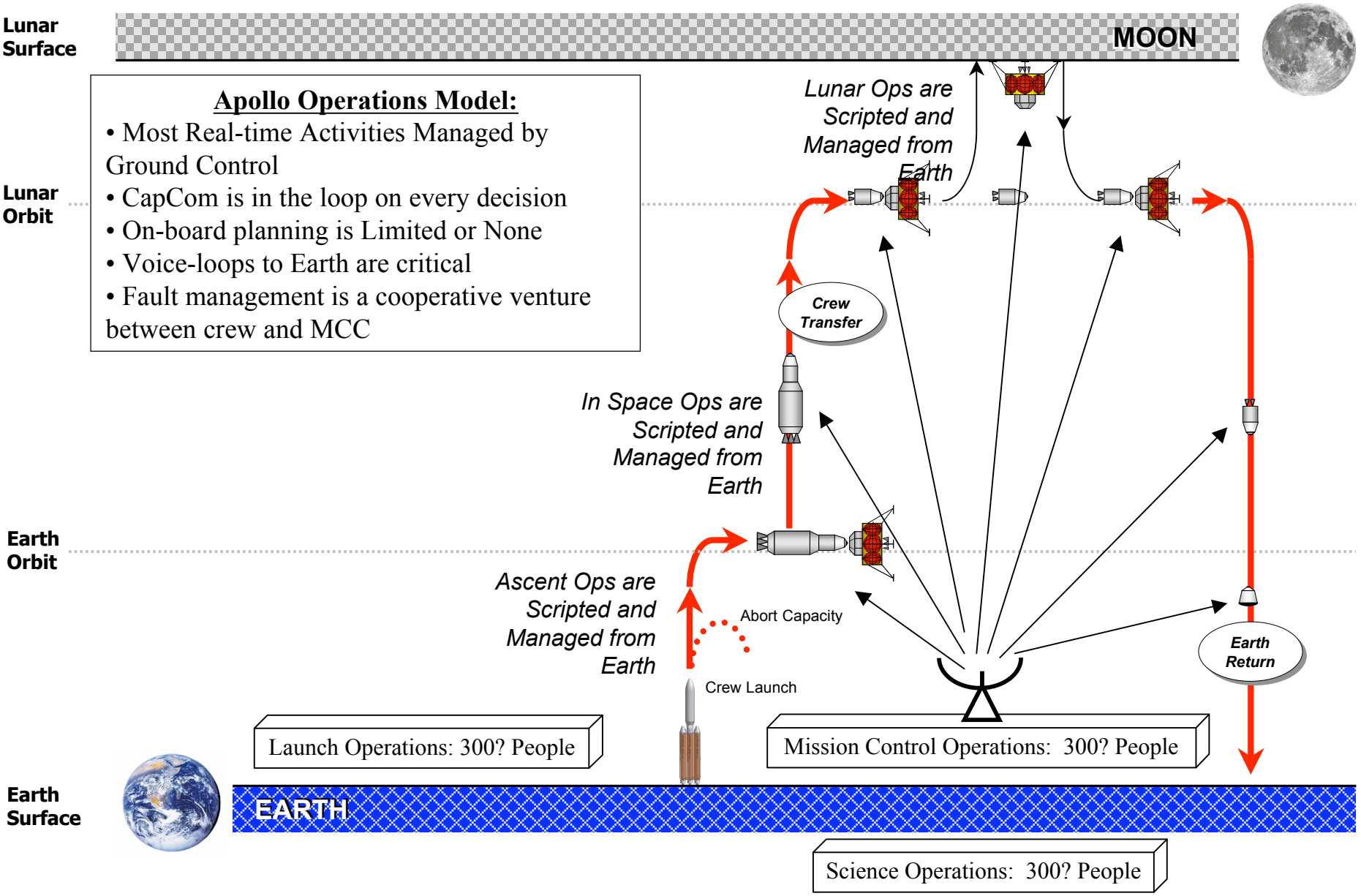
• CEV

• CEV
• LSAM

Human Factors of IVHM on Next-Gen Vehicles

Apollo Operations Model:

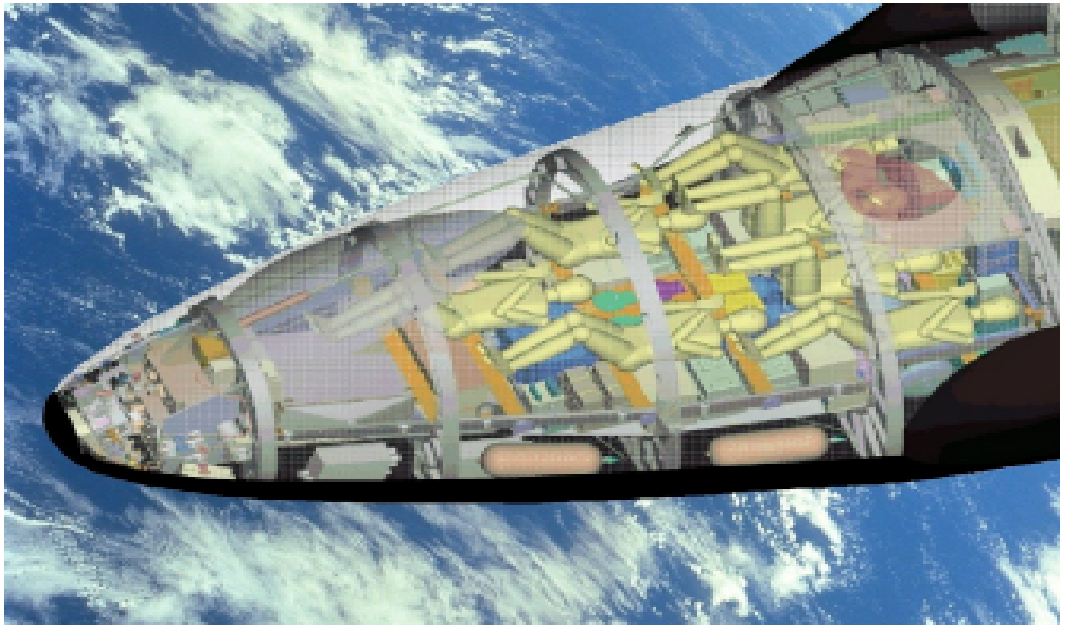
- Most Real-time Activities Managed by Ground Control
- CapCom is in the loop on every decision
- On-board planning is Limited or None
- Voice-loops to Earth are critical
- Fault management is a cooperative venture between crew and MCC



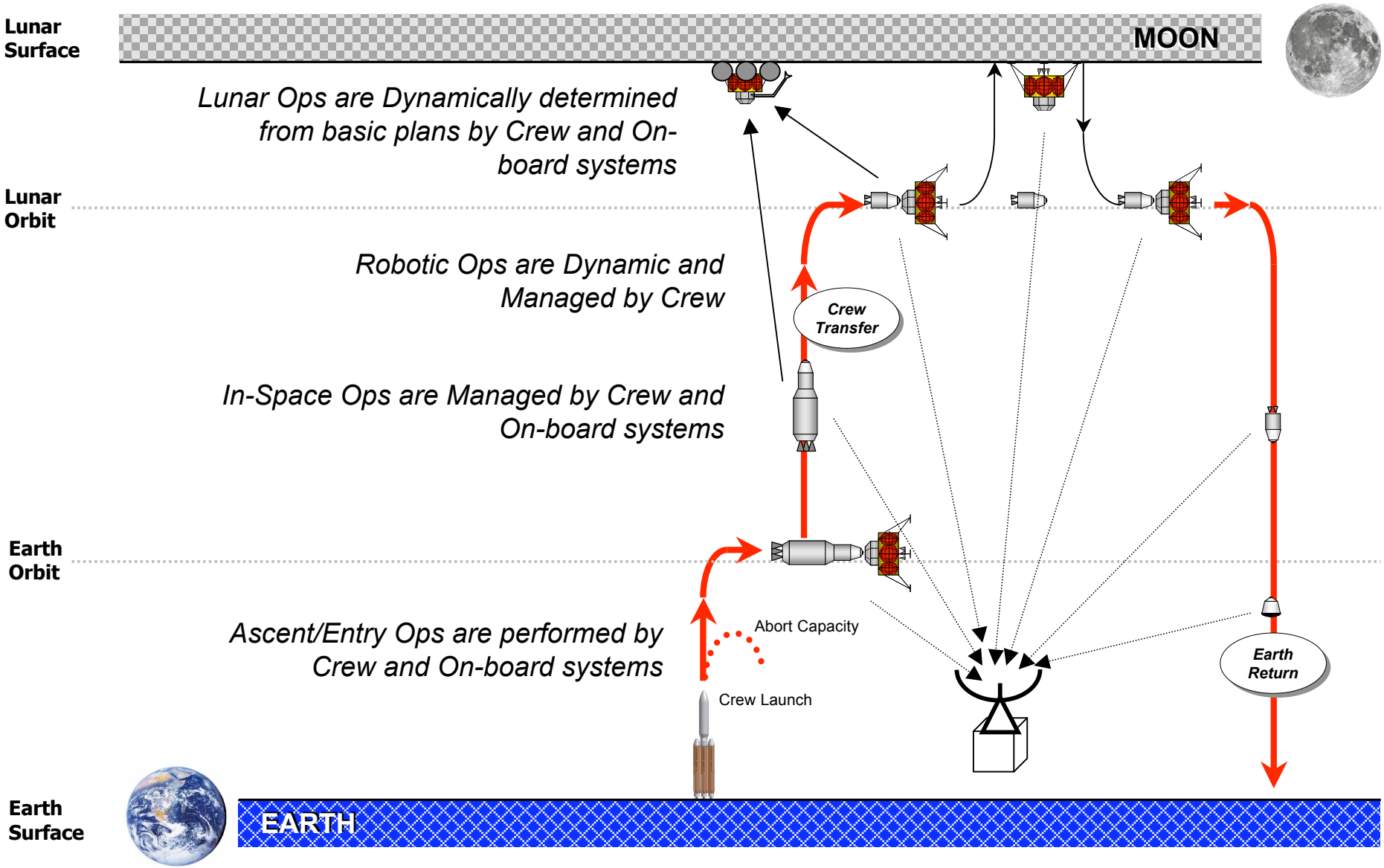
- **How should CEV be Operated?**

  "... In our planning, we wanted to ensure that we were designing systems with the maximum possible applicability to future missions to Mars"

  - NASA Administrator Mike Griffin
    Aug 31 2005



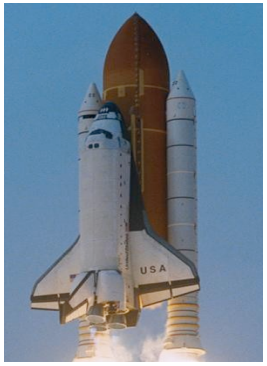
Exploration Missions: Crew-Centered Operations Concept



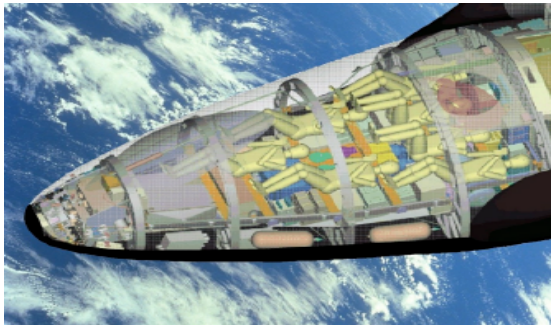
Human Factors of IVHM on Next-Gen Vehicles

Where are we today?

- On board Fault Management on Shuttle



- What do we need:
  - Enhanced Fault Management Automation



- How do we get there?
  - Mixed-initiative concept for onboard CEV fault management

Human Factors of IVHM on Next-Gen Vehicles

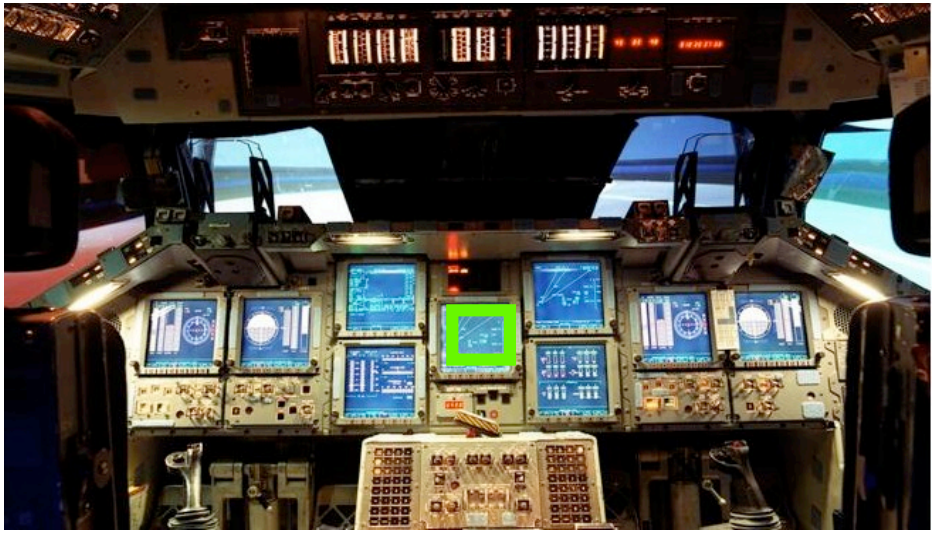
• Spacecraft contain very complex propulsion, life support, guidance, communications, and electrical and mechanical power systems

• Each one is highly interconnected, and must operate to very precise standards under harsh environmental conditions

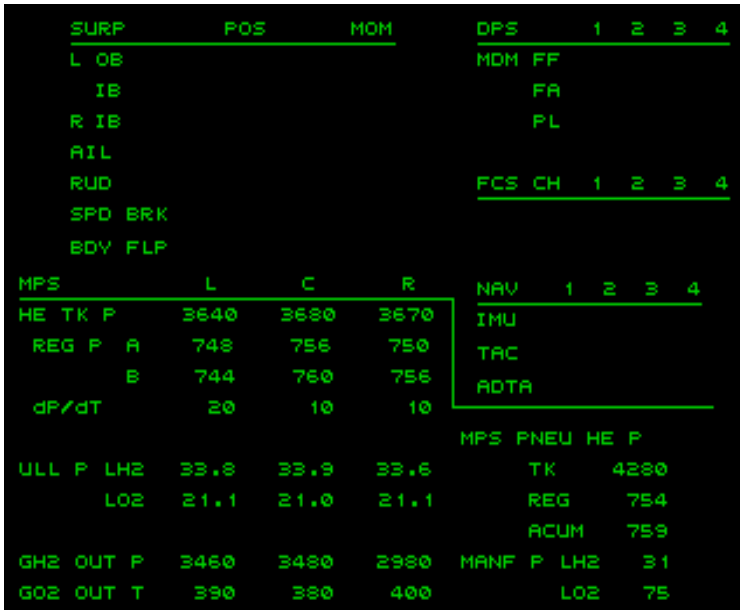
• **Managing the health of spacecraft systems is a major component of real-time vehicle operations**
  - **Entails dramatic real-time information acquisition and information processing requirements**
    - – Functional status of these systems must be monitored at all times
    - – If an operational problem is encountered, it must be:
      - detected
      - diagnosed
      - dealt with

Human Factors of IVHM on Next-Gen Vehicles

- How are these operational requirements met in today's cockpit?
- Each system is instrumented with scores of sensors that continuously measure critical operating parameters: temp, pressures, flow rates, etc.



"Current MEDS" Cockpit



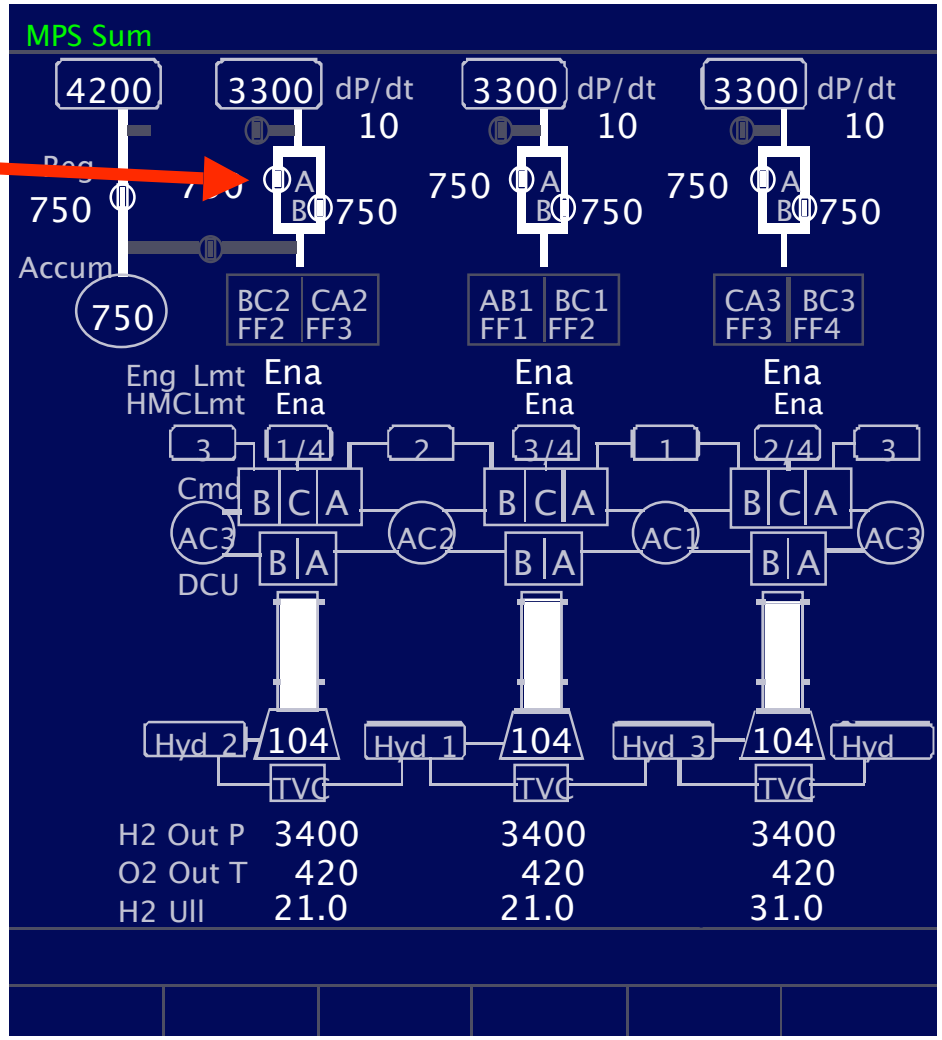
BFS GNC SYS SUM 1 Display

- Each sensor produces a continuous stream of data
- Subset available on Cockpit System Summary Displays
- Caution and Warning (C&W) System performs limit sensing on selected parameters (data streams)

Main Engine Malfunction Scenario: Left Engine Helium Supply System

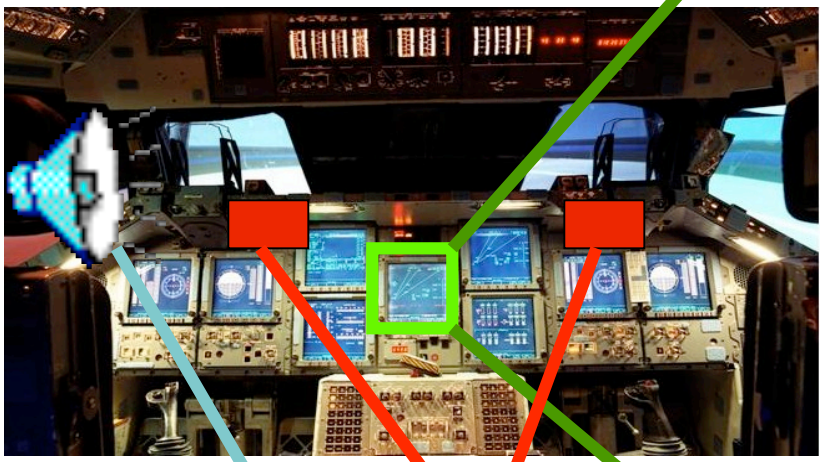
- Left Engine Leg A Isolation Valve Failed Closed

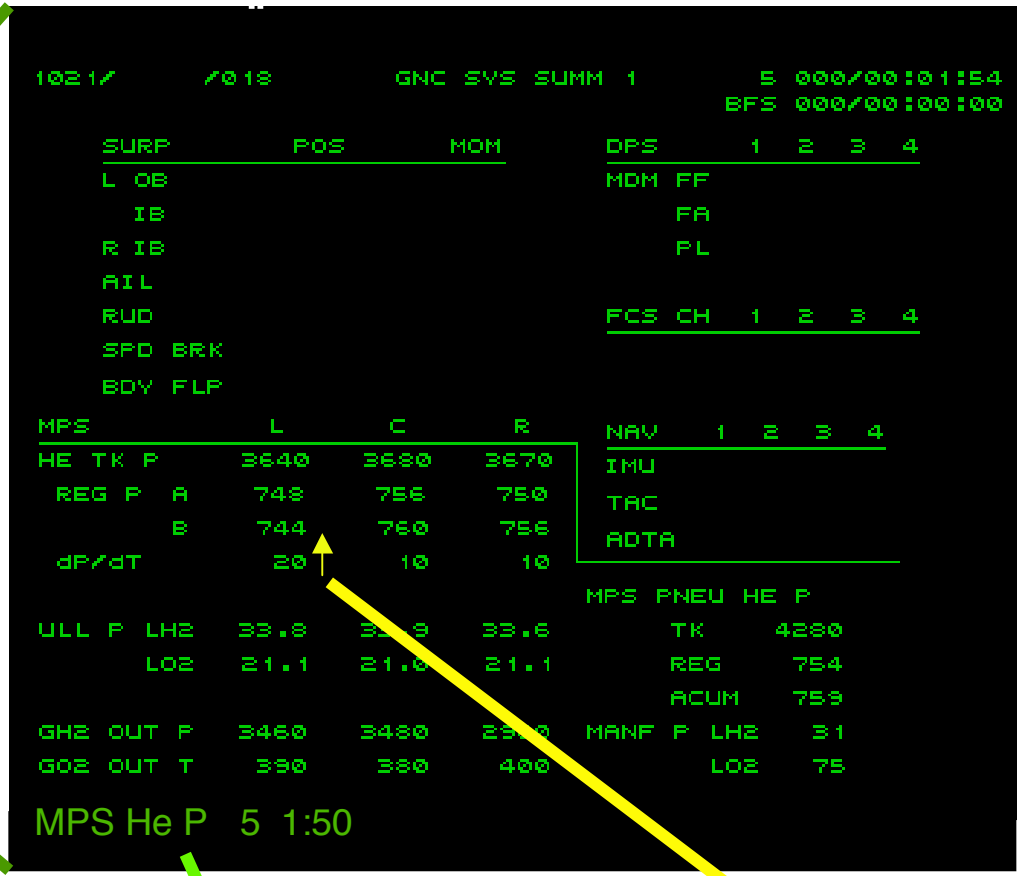
- Introduce Helium Leak



Fault Management Example: Left Engine Non-Isolatable Helium Leak

Cockpit Indications:





MA Light

Auditory Tone(s)

"Up" Arrow

Flashing Fault Message

Human Factors of IVHM on Next-Gen Vehicles

MPS	L	C	R
HE TK P	3640	3680	3670
REG P A	748	756	750
B	744	760	756
dP/dT	20	10	10
ULL P LH2	33.8	33.9	33.6
LO2	21.1	21.0	21.1
GH2 OUT P	3460	3480	2980
GO2 OUT T	390	380	400

MPS He P 5 1:50

MPS He P (Pre MECO)

1. √dP/dT

If after MECO-60:
2. Shut dn MN ENG per MPS CMD/HYD/ELEC >>

If He REG P↑ or↓:
3. Aff He ISOL - CL

Otherwise :
4. Aff He ISOL A - CL

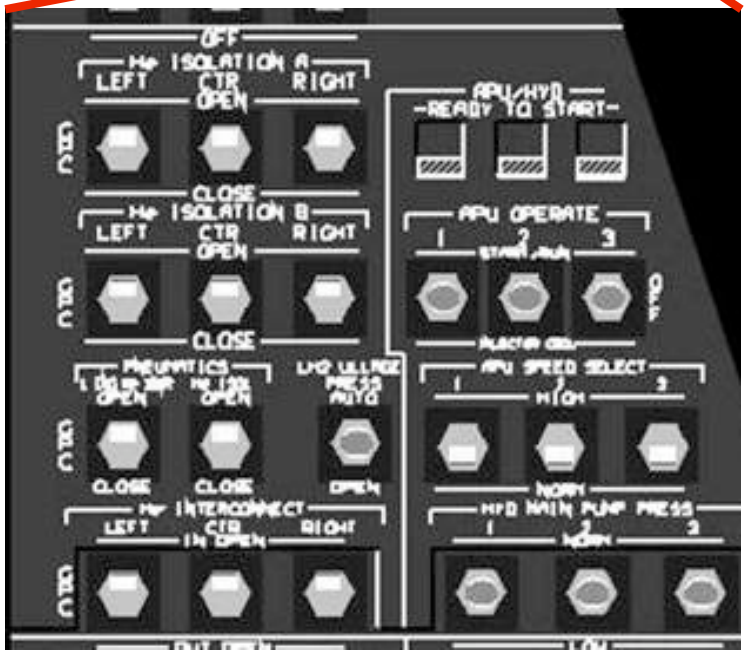
If no decr in dP/dT:
5. Aff He ISOL A - OP
B - CL

If no decr in dP/dT:
6. Aff He ISOL B - OP

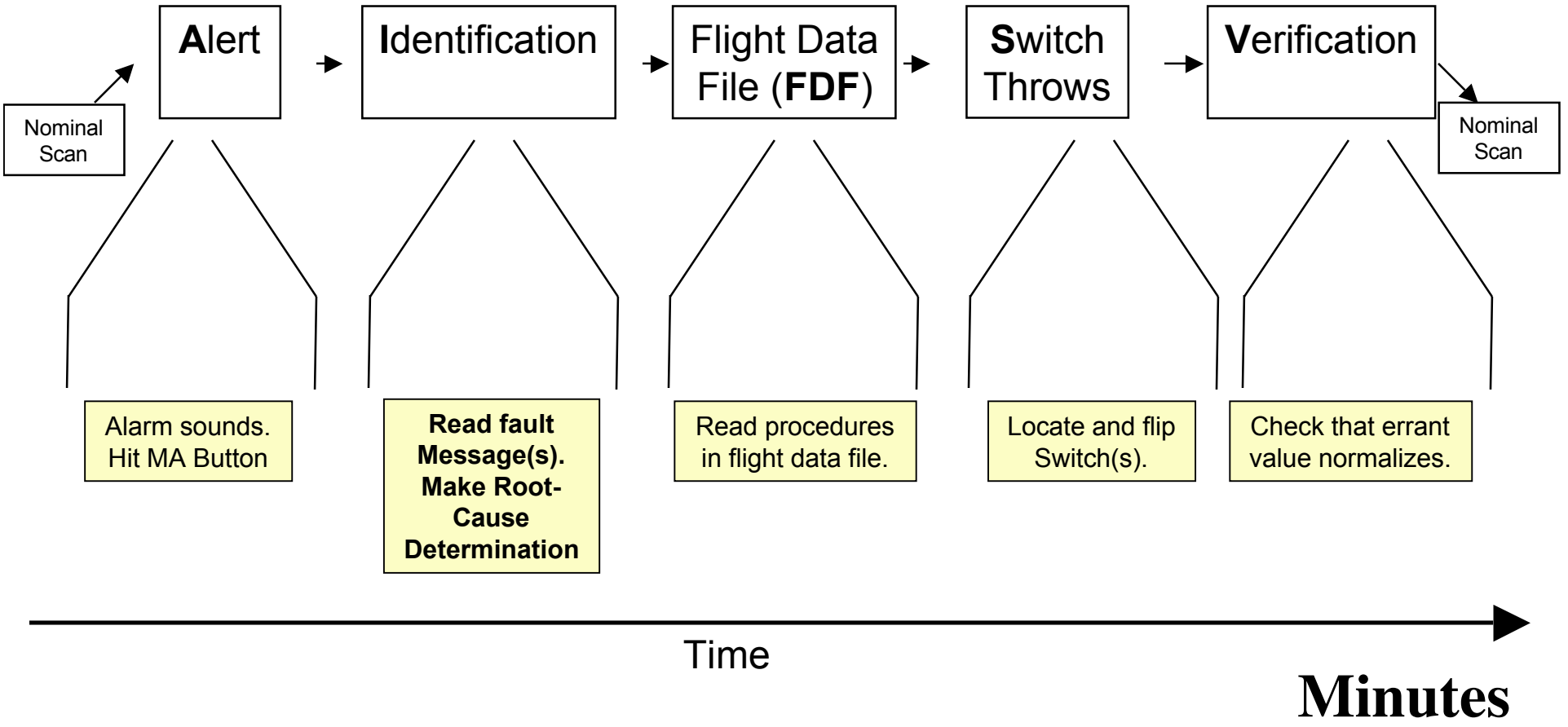
If any ENG failed:
7. Failed ENG He I'CNCT - OUT OP

If nonisolatable:
8. Shut dn MN ENG per MPS CMD/HYD/ELEC
If/when TK P < 1150 or REG P < 679 :
9. Aff He I'CNCT - IN OP

FDF



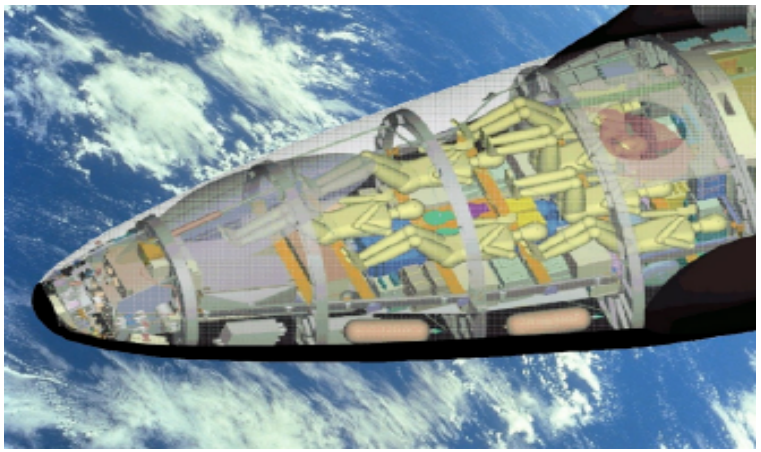
Fault Management Stages



Real-time Spacecraft Operations:

Current operation:

- **Unwieldy** (too long, too demanding)
- **Unsafe** (diverts crews attention from other critical other information processing requirements)
- **Unacceptable** for Next-Gen vehicle



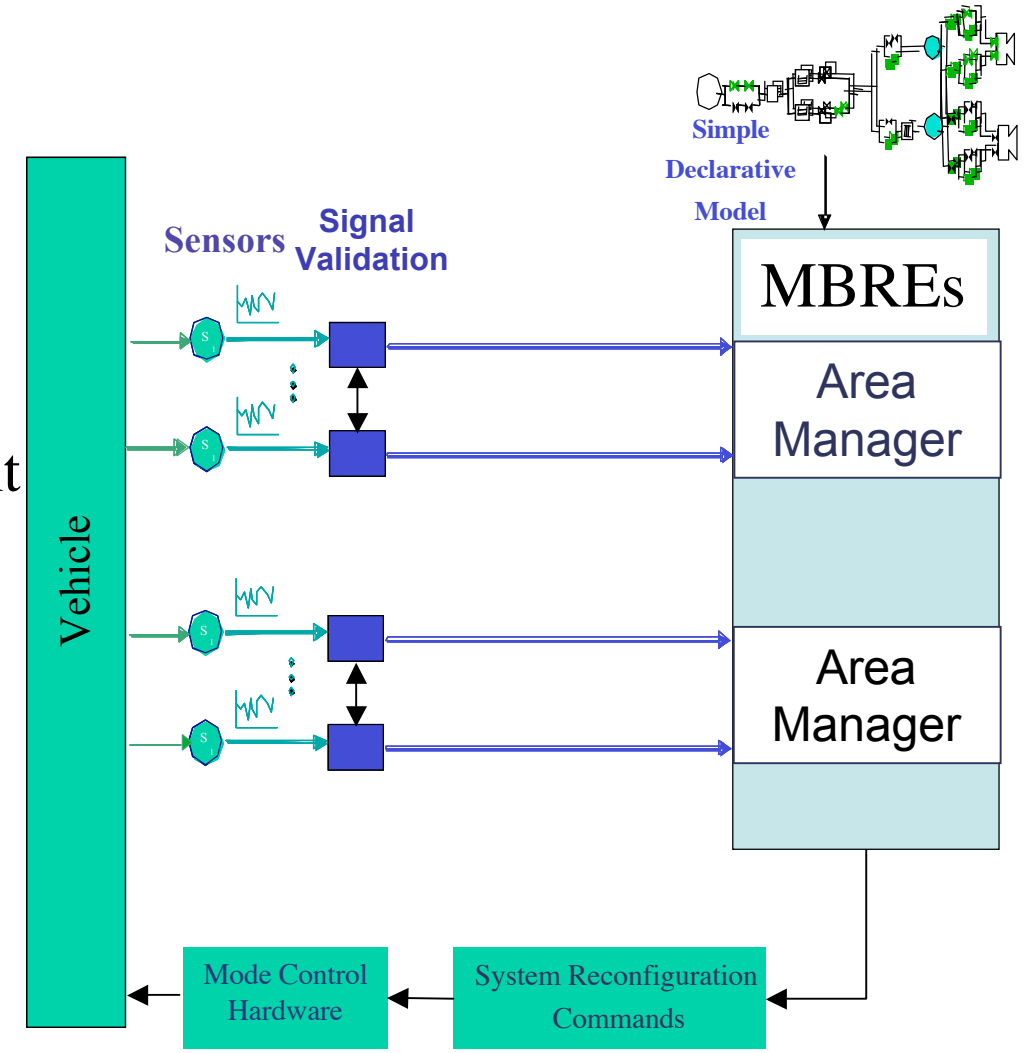
Solution:

- Automate constituent functions
- Build concept for human-automation collaboration

Human Factors of IVHM on Next-Gen Vehicles

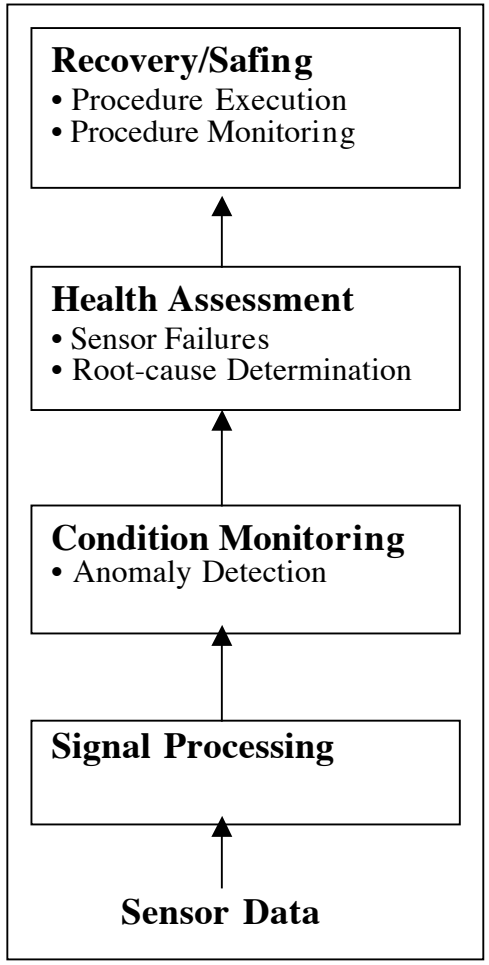
Capitalize on last 25 years of advances in:

- Computer processing speed
- Memory capacity
- Distributed & parallel processing architectures
- Flight and Health Management Software (IVHM) Systems

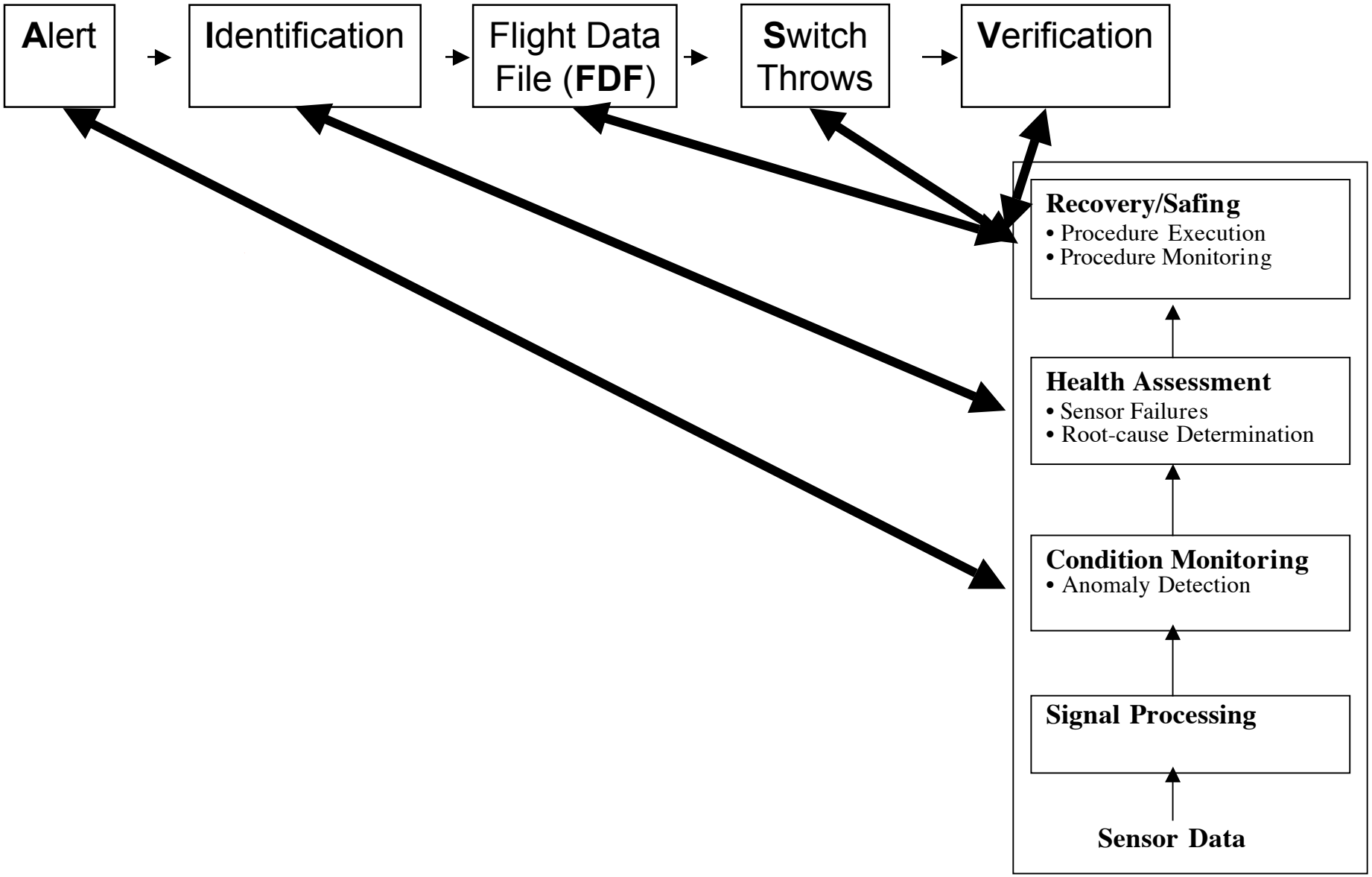


Human Factors of IVHM on Next-Gen Vehicles

• State of the art automated health management system (Keller, Wiegand, Swearingen, Reisig, Black, Gillis, & Vandernoot, 2001)



Human Factors of IVHM on Next-Gen Vehicles



Should we automate completely?

- 3 Compelling reasons why not:

1. Limits to automated capabilities:

    - Fault diagnosis:
        - Reasoners don't yet have full fault coverage

    - Software/Hardware subject to failure

    - Humans have to act as backup
        - OOTLUF problem with full automation

2) Humans are SME's too
   - Taking them out of the loop amounts to wasting onboard expertise

3) Humans and Machines have different processing strengths and weaknesses
   - Frequency complement each other

➢ By actively partnering, they can
   - Augment each other's capabilities
   - Back each other up in case of failure

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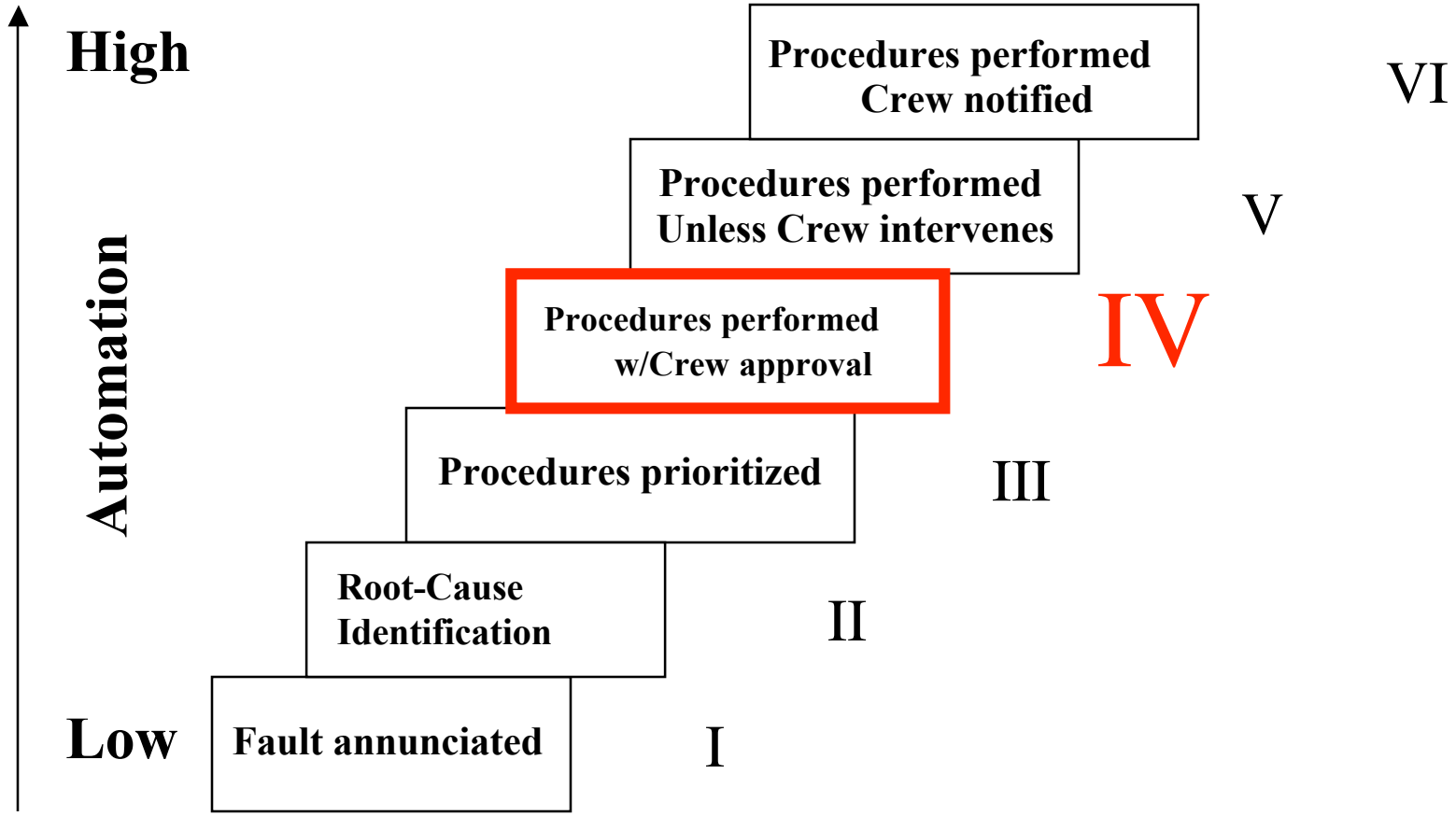
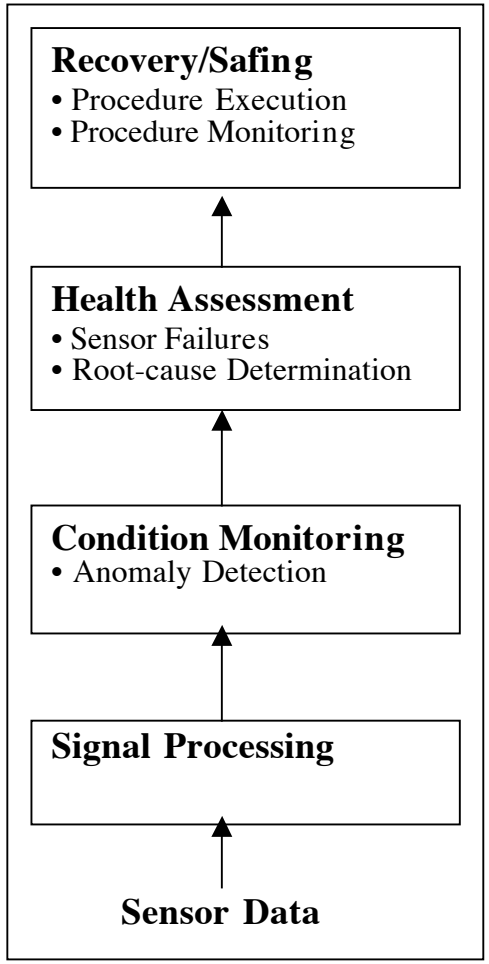
Human Factors of IVHM on Next-Gen Vehicles

- A concept for human-machine partnering
- Following McCann and McCandless (2003)



Human Factors of IVHM on Next-Gen Vehicles

- Making it work: Design Requirements



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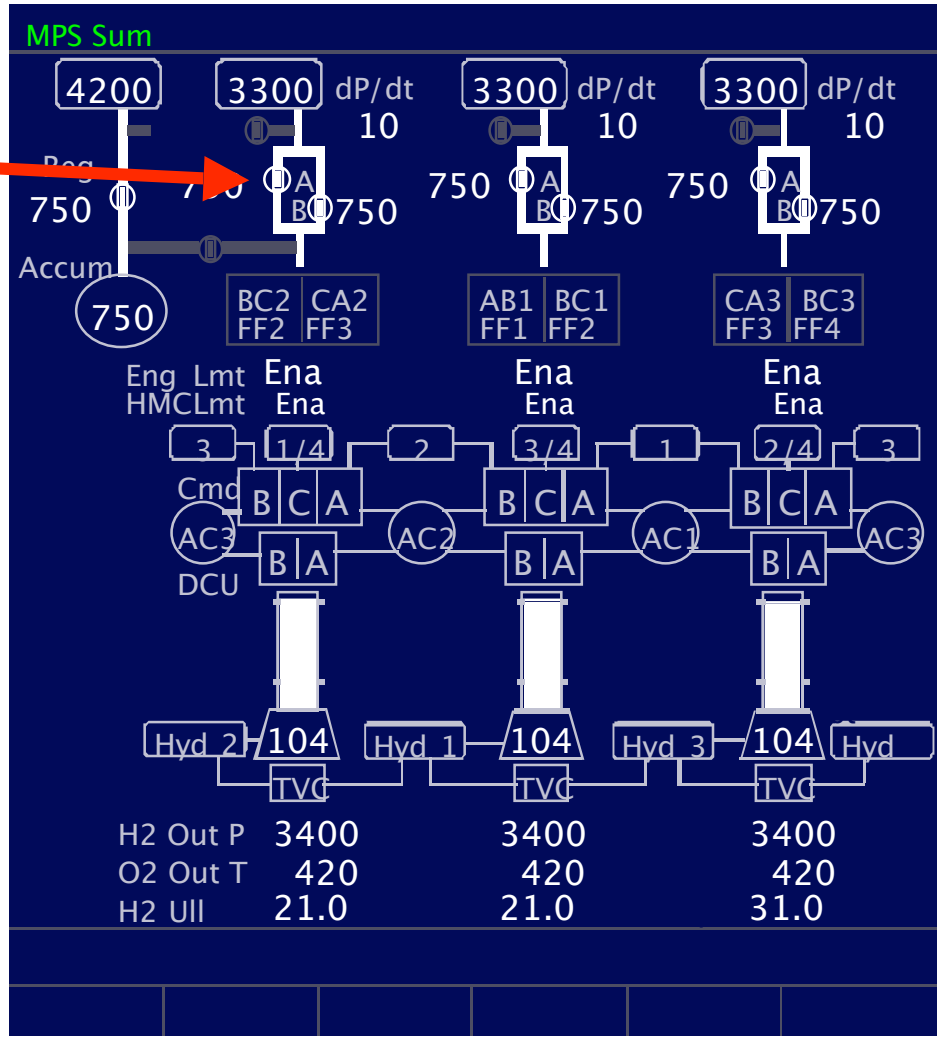
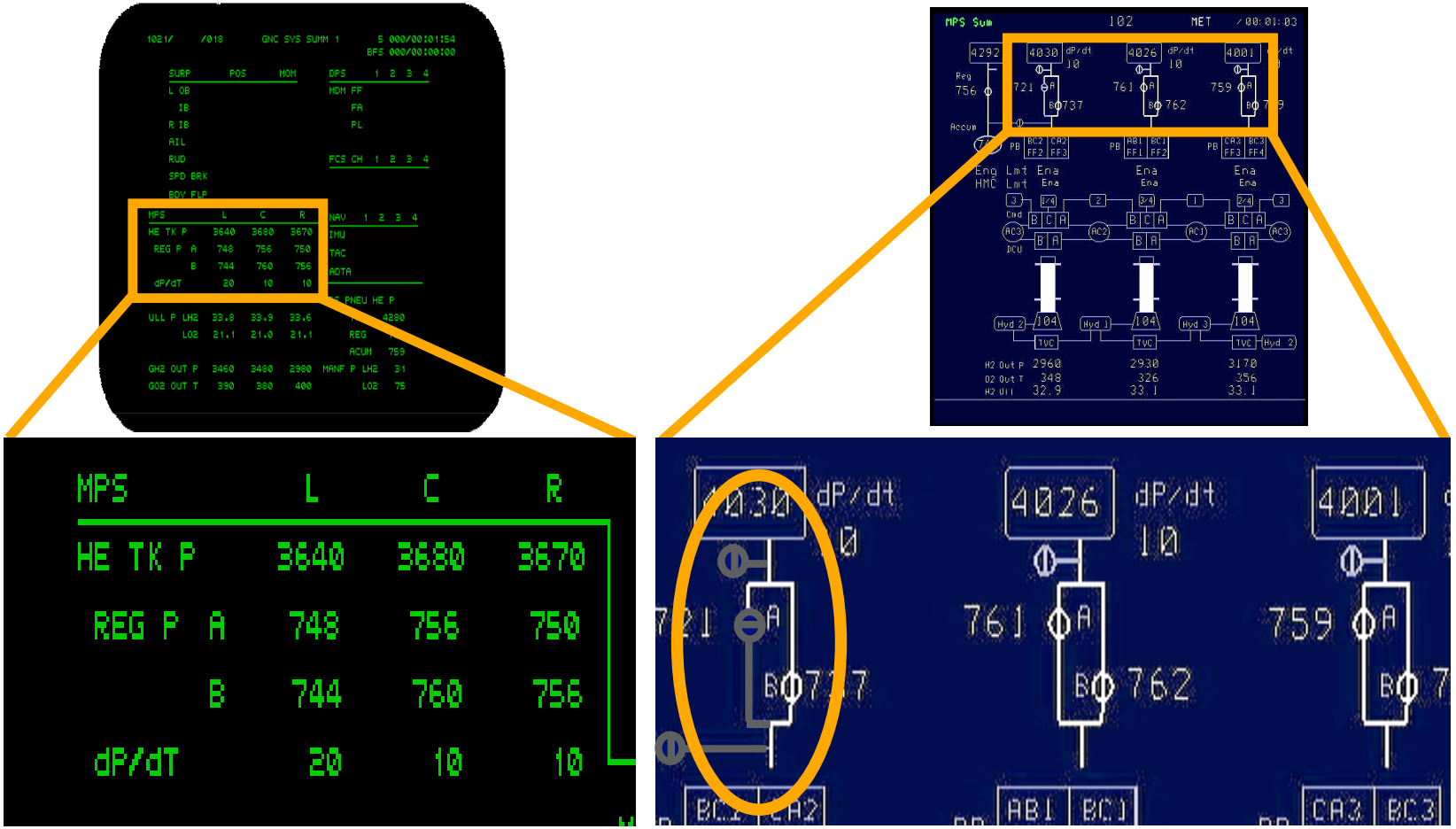
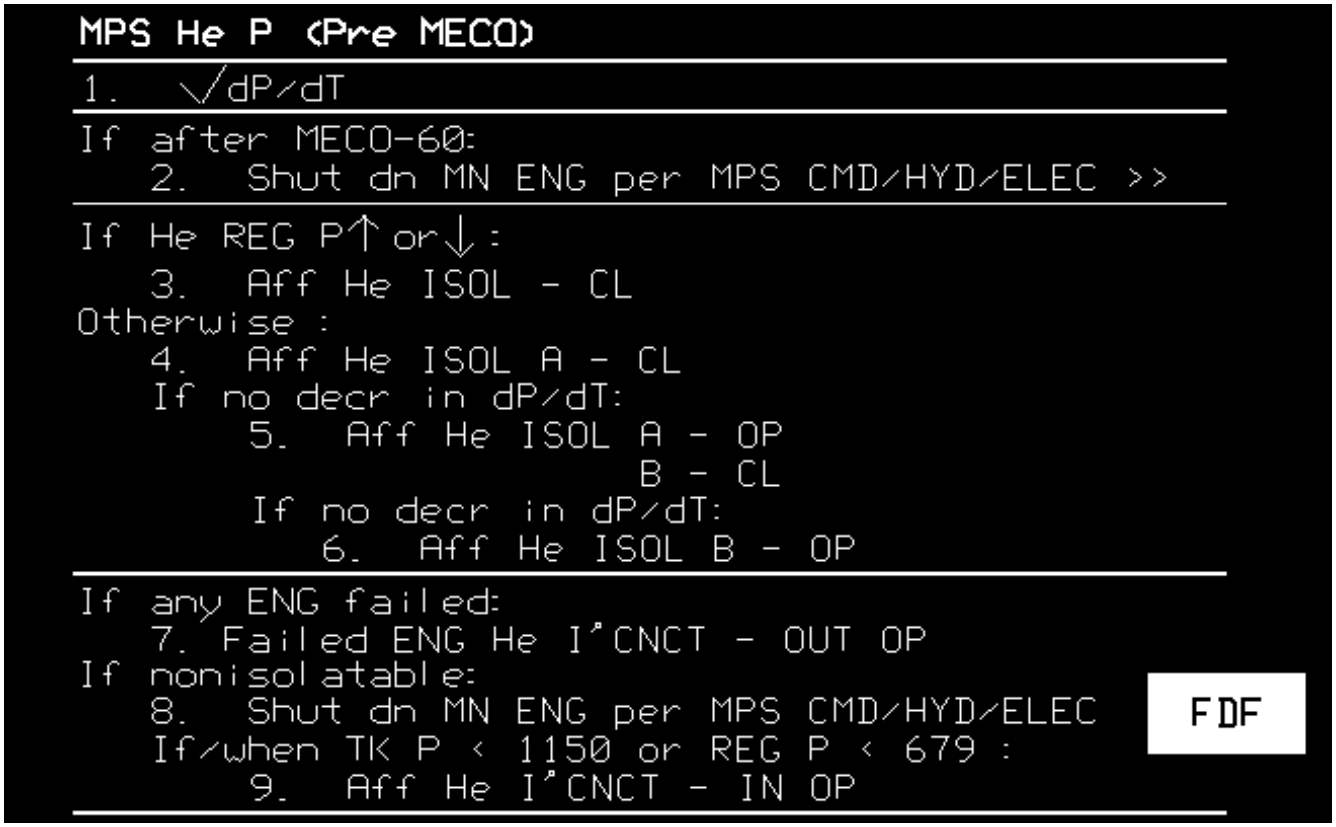


Human Factors of IVHM on Next-Gen Vehicles

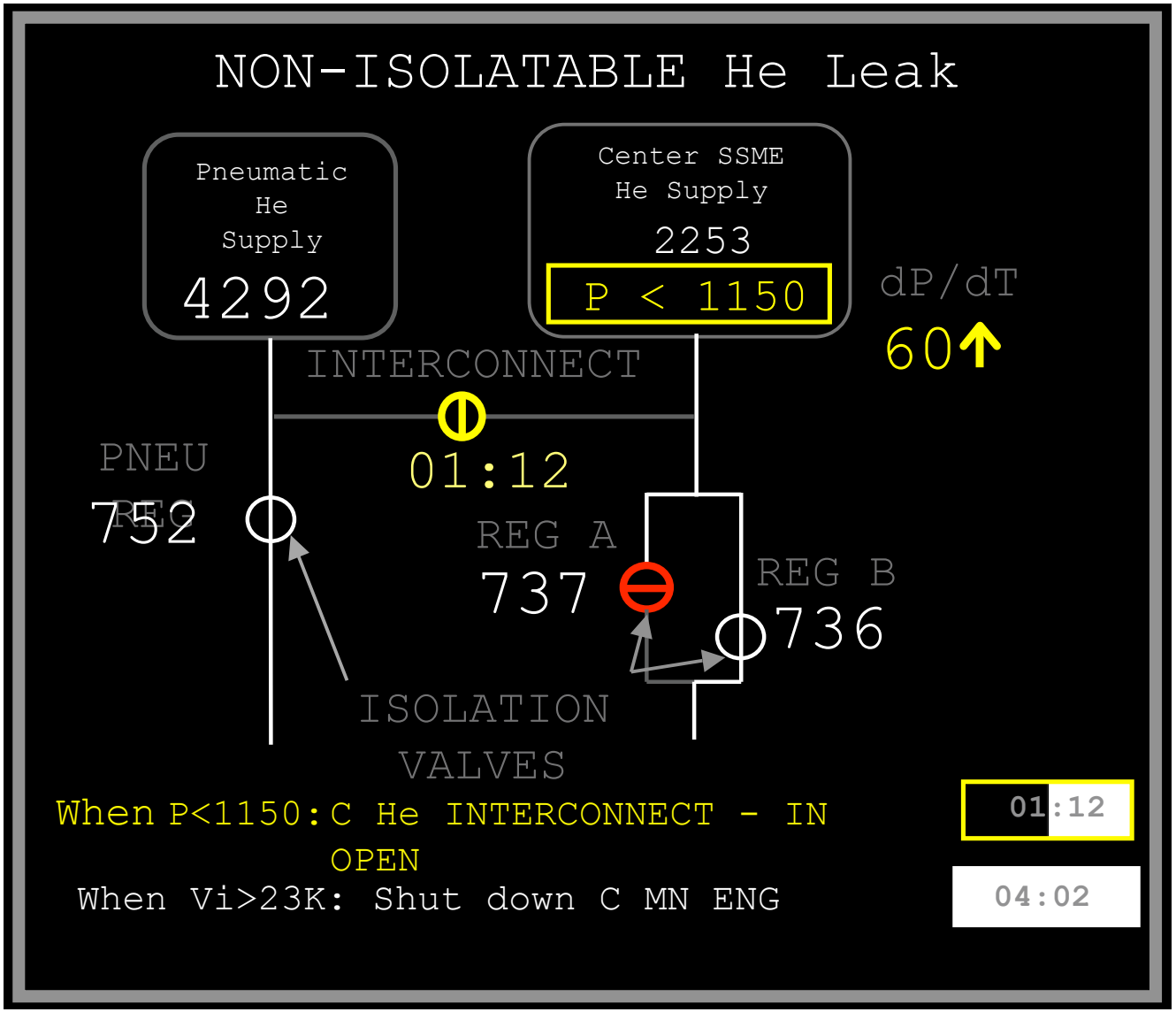
1) New interfaces to give direct insight into current functional mode

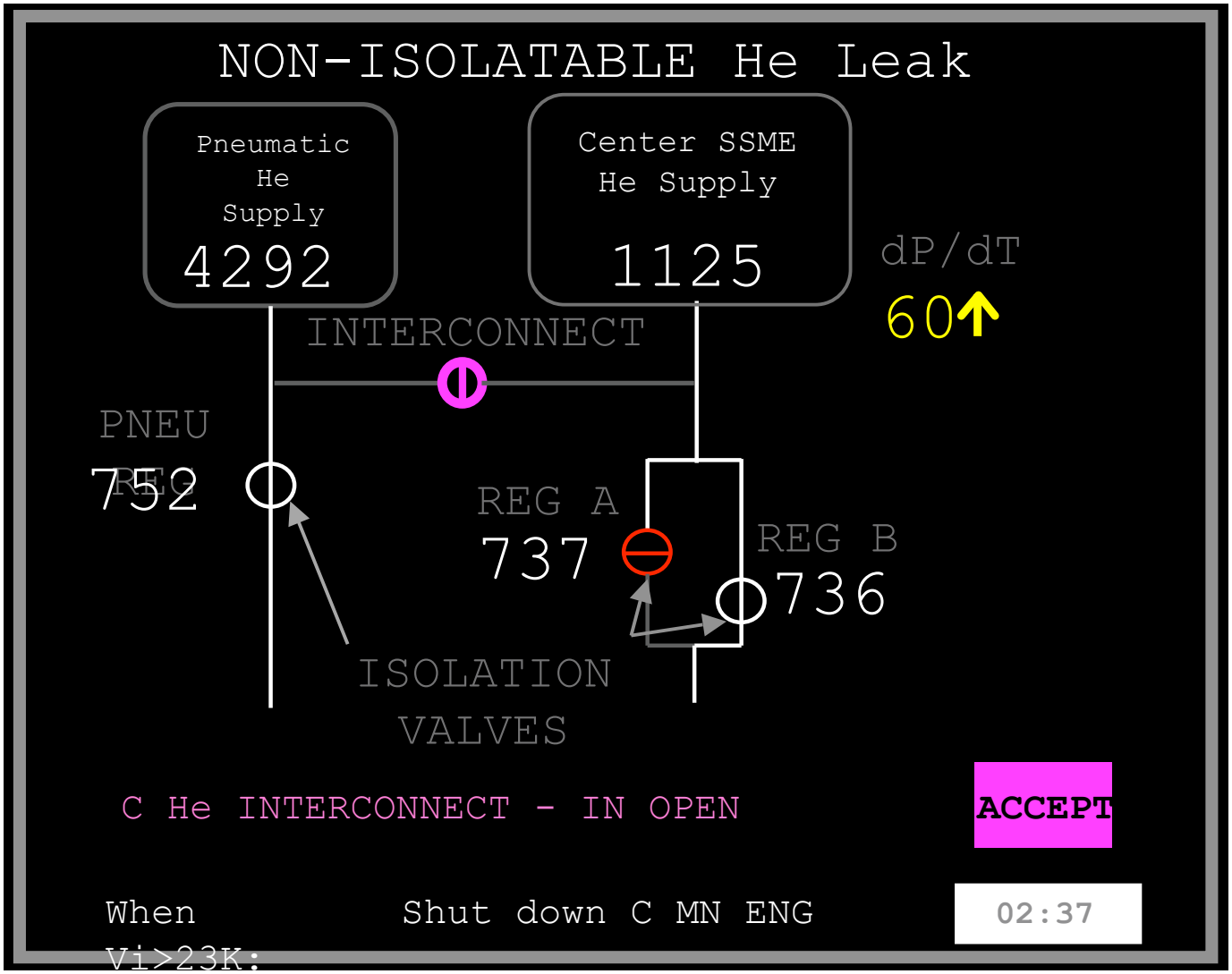


- Electronic Flight Data File



- Candidate Fault Management Display




NON-ISOLATABLE He Leak
Pneumatic He Supply
4292
Center SSME He Supply
1125
dP/dT
60
INTERCONNECT
PNEU REG
752
REG A
737
REG B
736
ISOLATION VALVES
C He INTERCONNECT - IN OPEN
ACCEPT
When Vi>23K:
Shut down C MN ENG
02:37

Natural Language Interfaces